IGS BURNER MODIFICATION REPORT

DRAFT

INTERMOUNTAIN POWER SERVICE CORPORATION
TECHNICAL REPORT- EXECUTIVE SUMMARY

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TITLE: Burner Modifications made at the Intermountain Generation Station, Units 1 and 2.

SUMMARY: In November of 1991, flame stabilizers were added to the burners and the register lineup was changed on Unit 2. In April of 1992, new burners with stabilizers were installed on Unit 1. In addition to these modifications, the following was also conducted on both units: extensive secondary air flow testing and balancing, primary air/coal flow balancing and a new burner register setup philosophy adapted. These modifications were required due to mechanical and structural thermal degradation observed on the burners. This was primarily due to an overheating condition caused when burners were in an out-of-service condition.

CONCLUSIONS: Based on windbox and fireside inspections since modifications, the burners are reported to be in excellent condition. The high rate of mechanical and structural degradation due to overheat conditions have been curtailed. This has been accomplished without changes to the operating criteria of the burners or boiler, which would have had adverse impact on performance or emissions.

The new burner setup has functioned well, without overheating or pluggage to the flame stabilizers. LOIs, NO_x levels and flame stability have all proved satisfactory. Modifications made to the burners have been effective and long life of the burners has been renewed.

It is not known, however, if we can expect full life out of Unit 2's burners since they were not replaced. At this time, no foreseeable replacement will be required over the next five to ten years. However, replacement may be inevitable due to pre-existing damage.

Coal nozzle flaring has been observed on some of the burners during outage inspections. This seems to occur randomly and effects 5 to 10 percent of the burners.

RECOMMENDATIONS: Continue to maintain existing burner register setup and flame stabilizer installation. Periodic inspections of the burners will also be continued during major outages.

Additional investigation and testing needs to be conducted to address the nozzle tip overheating, causing some to droop or become out of round. This may be addressed by a materials change or possibly by moving the flame front further out.

More analysis into burner line aerodynamics needs to be conducted to address burner line fires. Coal transport line fires, however, is an unrelated issue to the mechanical degradation observed on the burners.

PREPARED BY: ____________________ DATE: __________

APPROVED BY: ____________________ DATE: __________
Superintendent

APPROVED BY: ____________________ DATE: __________
President and Chief Executive Officer

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SECTION 1 - INTRODUCTION

This report summarizes the burner modifications and results made on Units 1 and 2 at the Intermountain Generating Station. These modifications were recommended based upon serious concerns to the mechanical and structural integrity of the burners. IPSC felt that the original equipment manufacturer (OEM) had not adequately resolved the thermal degradation issue. However, the integrity issues had been addressed and various modifications were attempted. IPSC's contention was the damage was not caused by misoperation and that the burner components should be able to handle the steam generator "guaranteed" operating conditions.

IPSC felt these issues constituted enough of a safety risk to pose a potential mechanical or structural failure of a burner. Several outside consultants were hired to get third party opinions and to recommend possible solutions. These recommendations were packaged and evaluated by Los Angeles Department of Water and Power (DWP), the operating agent, and Intermountain Power Service Corporation (IPSC), the operating entity. The recommendations proposed were to address resolving the mechanical aspects of the burner, with the intent of not degrading any of the combustion or performance parameters. It should be noted, that after original acceptance testing and subsequent tuning of the burners and boiler, performance and combustion of the burners have been very good.

It was agreed to modify the existing setup on the burners on Unit 2 and that the burners on Unit 1 would be redesigned and replaced in full due to their degraded condition. Babcock & Wilcox (B&W) was retained as the burner manufacturer. RJM Corporation (RJM) provided finite element analysis capability and design consultation.

In November of 1991, the existing Unit 2 burners were repaired and modified to better handle thermal expansion and flame stabilizers were installed. Other alterations were also made, which included improved burner register setup, secondary air flow balancing and primary air/coal flow balancing. Based upon the outcome of these modifications, Unit 1's burners were replaced with new enhanced design burners. Improvements included material changes (309 SS) and increased thickness of components in key areas. Flame stabilizers were also added, register lineup changes made and balancing of the secondary air and primary air/fuel were also conducted to this unit.

The conclusion was that the modifications made to the burners have been successful. Thermal degradation and mechanical damage has been greatly reduced. However, overheating and flaring is still occurring to some of the nozzle tips and is being investigated. Some of the combustion and performance parameters dropped slightly (LOI and NO_x levels), but did not have significant adverse impact on the operation of the burners.

UNIT DESCRIPTION

The two Babcock & Wilcox coal fired steam generators at the Intermountain Generating Station are subcritical, single drum, opposed fired, balanced draft, parallel backend, Carolina type radiant boilers. Furnace dimensions are 85 feet wide, 60 feet deep and 229.5 feet high from the lower wall header to the drum center lines (reference cross sectional view).

Each unit fires pulverized coal from 48 low NO_x dual register burners, arranged in four rows of six burners on both the front and rear furnace walls. Secondary air is provided to the compartmentalized windbox by a wrap-around windbox (plenum principle). No individual burner row air flow measurement is provided.

The Mark V B&W burner is a low NO_x design, two zone burner with a conical coal diffuser. The inner and outer registers rotate secondary air flow in the same direction, with the three right hand burners spinning counter clockwise and three left hand burners rotating air flow clockwise into the furnace.

Eight pulverizers supply primary air and coal to six burners at 150 F. Normal operation requires seven pulverizers to be in-service, with the eighth pulverizer out for routine maintenance and overhauls. The seventh pulverizer is redundant and can be taken out on an emergency basis for maintenance repairs. Therefore, as many as twelve burners may be taken out of service, while still providing full load availability to the unit.

Coal, supplied from Utah, is bituminous, underground mined coal. Typical fuel quality is as follows:

TYPICAL COAL QUALITY

Heating Value (Btu/lb)	11850	Carbon (%)	65.0
MAF Heat Value(Btu/lb)	14275	Hydrogen (%)	4.60
Total Moisture (%)	8.10	Nitrogen (%)	1.15
Air Dry Loss (%)	6.00	HGI Index	44.5
Ash (%)	8.90	Ash Softening Temp (F)	2285
Sulphur (%)	0.45	Ash Na_2O Content (%)	1.80

The boiler maximum continuous rating of each unit is 6,600,000 lb/hr of main steam at 2640 psig at 1005 F at the superheater outlet, with a reheat steam flow of 5,285,000 lb/hr at 551 psig and 1005 F. Unit design was based on constant and variable turbine throttle pressure from 25% to 100% load. The units do not use gas recirculation for temperature or NO_x control.

Startup on Unit 1 was in February of 1986 and went commercial on July 1, 1986. Unit 2 started up in February of 1987 and went into commercial operation May 1, 1987.

SECTION 2 - HISTORY

During the Unit 1 Boiler Performance Acceptance Testing in the summer of 1986, it became apparent that the boiler performance guarantees (main steam and reheat temperature, with an upper pulverizer out of service and boiler efficiency) could not be met without making crucial adjustments to some of the boiler operating parameters. The primary parameter that was changed was the allowable burner front metal temperature (for out-of-service burners). This was done to reduce the cooling air flow requirements to the burners (which contributed heavily for failure to make the main steam temperatures and boiler efficiency dry gas losses). However, the compromise of reducing cooling air flow is the protection on overheating the burners.

The original temperature setting on the outer register backplate assembly was 1200 degrees F. The recommended change from Babcock & Wilcox (B&W) was 1350 degrees F. It quickly became apparent the criticality of knowing all burner temperatures, since cooling air flow measurements are not available. All burners were then instrumented with two thermocouples. One attached to the backplate of the outer register assembly (overheat protection) and the other to the coal nozzle (burner line fire protection). Originally, the project installed four thermocouples on every other burner on alternating rows. Shortly after the burner maximum temperature limit change was made, problems were noticed with the burner register mobility as well as accelerated structural and mechanical damage to the burner components.

Babcock & Wilcox was notified of these problems and they attempted to correct these problems through various design alterations. A reviw of these burner modifications for Unit 1 are summarized by year as follows (information taken from IPSC outage inspection reports):

November, 1986 - Repaired many failed welds, straightened warped register plates, replaced rope packing, installed reinforcing band in packing area, straightened door shafts and repaired register linkages.

April, 1987 - Inner air sleeves on many burners were barrel shaped and distorted. Carbon steel reinforcing bars were exfoliated, many welds broken, backplates were warped and many of the doors would not adjust. Backplate attachment was modified to try and stop warping. Three nozzle tips were replaced due to fire damage and several more showed signs of overheating.

IPSC installed 30 additional thermocouples so overheating damage could be documented and corrected (see Attachment 1, April, 1987, Outage Report).

November, 1987 - *B&W construction installed new heavy duty (HD) registers on both the front and rear burners on level four* as a trial to determine if the new register design would allow outer register adjustment while on-line. The 22 inch alloy tips on all 48 coal nozzle assemblies were replaced with a new 33 inch alloy tip. Modifications were made to the throat and inner air sleeve attachment to the outer register frame front plates. A register retaining lug and clip system replaced the previous weld attachment. These modifications were made to eliminate recurring weld cracking and permit thermal expansion between sections of the burner register assembly (see Attachment 2, November, 1987, Outage Report).

April, 1988 - The outer register vanes were trimmed in a trapezoidal shape to prevent vane binding and freezing. The binding was occurring because the backplates continued to deform (oil can). Lighter shrouds were replaced on two burners. Many welds are still found broken. Burner to waterwall seal was missing on almost all burners (see Attachment 3, April, 1988, Outage Report).

April, 1989 - Even though burner backplate temperatures were maintained below the B&W recommended 1350 degrees F., evidence of overheating damage was found. Permanent warping, rippling, barreling discoloration, flaking and thermal expansion damage was observed on the heavy duty and standard outer register assemblies, register vanes, drive handles, throat sleeves, inner air sleeve casing rings and lighter shrouds.

IPSC decided at this point that an outside consultant was needed to do an independent evaluation of the burners and estimate remaining burner life (see Attachment 4, April, 1989, Outage Report).

April, 1990 - Energy and Environmental Research (EER) Corporation was hired to do an evaluation of the burners. They inspected the burners and concluded that "excessive temperatures have severely warped the stainless steel components and exfoliation of the carbon steel exists on 20 separate burners. The burners are also improperly supported which, along with the high temperature conditions, results in permanent warpage of the burners. In an effort to correct these problems, the burners have received field modifications that have created additional stresses." It was EER's recommendation that the burners be redesigned and replaced (see Attachment 5, EER Report).

April, 1991 - The burners were in the worst shape to date. William Newkirk, an ex-employee of B&W and independent consultant, came on-site to inspect the burners. He found numerous evidence of overheating. In his report he indicated that the burners only had two to five years remaining life. He raised serious concerns about a possible furnace explosion caused by overheated damaged burners. Some of the outer air register spin vanes got so hot that the steel went molten (see Attachment 6, William Newkirk Report).

SECTION 3 - GOALS AND PURPOSE OF BURNER MODIFICATION PROJECT

Despite all of the mechanical reliability problems that were experienced with the initial burner design, the actual operational performance of the burners remained good. Boiler performance, NO_x levels, ash loss on ignition (LOI) and flame stability were all acceptable based upon the original setups. The justification for redesigning and replacing the burners was based solely on physical damage that was occurring due to overheating. Modifications were not expected to improve the combustion and performance of the burners. The dual register design, originally supplied by B&W, had excellent combustion characteristics and the intent was not to deviate from that basic burner design philosophy.

The established goals and design criteria for the project were as follows:

Goal 1: Design and install a burner that can structurally handle the operating temperatures, both in and out of service, without deformation or exfoliation. Additionally, the burner registers must be operable both in and out of service conditions. This should be done at the lowest possible cost.

Goal 2: The new burner design should be able to operate with only minor maintenance for 25-30 years.

Goal 3: The combustion performance and operating parameters of the burners should remain about the same or better than they were originally.

SECTION 4 - PROJECT DEVELOPMENT

With the end of the boiler warranty period, efforts began in earnest to identify alternative methods of quantifying and prioritizing the maintenance and operational impacts of the observed burner degradation. Several respected entities within the burner design/development industry were consulted.

Frequent discussions with B&W continued regarding appropriate tuning and/or modifications to correct burner degradation concerns. In one of many letters written during this period, B&W stated that without windbox specific flow measurement, it would be virtually impossible to achieve an air flow balance to meet both combustion and cooling requirements. Installation of the B&W proposed system for windbox airflow measurement was approximately $1,000,000 per unit.

Initially IPSC chose to involve Mr. Bill Newkirk, a retired B&W employee who, while with B&W, was responsible in large measure for the design and manufacturing quality assurance of the IGS burners. While on-site, Mr. Newkirk provided meaningful information with regard to both design and manufacturing concerns on the IGS burners. A copy of Mr. Newkirk's report is attached (Attachment #6).

Based on the rate of observed burner degradation and Mr. Newkirk's report, a survey was conducted within the burner industry to select a capable firm to assess the burner concerns and to provide economically based recommendations for resolution of these concerns. Energy and Environmental Research Corporation (EER) was selected to perform this evaluation. (See attached copy of the EER's report in Attachment #5.)

The recommendation from the EER report involved redesign and replacement of the entire register assembly, throat sleeves and casings. This report was reviewed with the original equipment manufacturer (OEM), B&W, to obtain whatever guidance they would provide. B&W responded with a new burner assembly for IGS. The new burner design, however, was essentially the same burner using thicker steel, a modified throat seal and a much more expensive alloy. The proposed new burner from B&W, based on B&W quotes, was approximately $1,600,000 just for Unit 1.

IPSC expressed concern, during B&W's presentation of their new burner, that just thicker steel sections would not enable the burner to withstand the significant thermal stresses occurring in operation. IPSC inquired into B&W's ability to perform a finite element analysis to support their new design. B&W responded that a finite element analysis would serve no meaningful purpose.

In an effort to fully assess B&W's proposal and investigate our stated concerns, it was felt that further outside investigation and analysis was justified. Discussions began with other sources knowledgeable in burner design and performance.

Among those consulted was RJM Corporation (RJM), a company specializing in burner performance and combustion profiling. Following on-site discussions and presentations from RJM, it became apparent that the problem was as much a function of burner design philosophy, as it was of burner stress analysis.

A program was proposed by RJM which included several parts. RJM was later given the go ahead to proceed with these evaluations:

- Conduct an aerodynamic flow evaluation of the burner using a two-dimensional flow model program of air flow through the burner. This analysis would establish proper register settings and criteria for flame stabilizer design.

- Conduct a secondary air flow balancing program utilizing inner and outer air zone measuring equipment. This would provide the basis for diagnosing unbalanced air flow through each burner and identify vortex generation zones.

- Conduct a structural finite element analysis to be performed on the burner assembly to identify specific areas of concern at various temperatures and at various temperature ramps. As part of this analysis, a temperature grid would also be generated from which "hot spot" analysis can be performed. This would allow proper dissipation of stress in areas experiencing the highest temperatures.

Among the more notable results of the finite element analysis were the design of a "petal" type backplate and verification that a much lower cost alloy would be satisfactory. Based on B&W quotes (to IPSC) dated September 12, 1991, RJM's verification of the suitability of the 304/309 stainless steel materials versus B&W's recommended Inconel 800H, produced a savings of approximately $620,000 and cut B&W's quoted material delivery time nearly in half.

Hindsight also suggests that the backplate modification recommendations alone, produced by this analysis, may well have prevented a reoccurrence of these same burner problems. The finite element analysis cost approximately $27,000.

- To address the combustion profile and air flow concerns associated with varying register settings for balance and cooling, RJM recommended installing fixed vane 'stabilizers' at the inner air throat. Tests, both foreign and domestic, had shown this type of assembly to provide stable ignition zones and minimize the harmful recirculation effects which were consistently observed on the IGS burners.

- RJM also strongly recommended modifying burner line restrictors to ensure proper fuel and primary air flow balancing. IPSC conducted clean air and dirty air flow testing and made required restrictor changeouts.

A team approach was established to redesign the burners. B&W assisted as OEM, RJM as design consultant and DWP's Power Design and Construction Group, assisted by IPSC, as manufacturing and installation quality control and assurance. With expedited support from DWP's Power Design and Construction Group, the modified burners were designed and manufactured in time to complete installation during the Unit 1 Spring 1992 Outage.

SUMMARY OF BURNER DESIGN MODIFICATIONS

Modification (what)	Objective (why)	Detail (how)	Provided By (who)
Unit 2 Burner Modifications	Reduce thermal degradation	Repair existing damaged burners Add flame stabilizers, balance air flow & lineup registers	Joint: RJM/ B&W/ DWP/ IPSC
Unit 1 Burner Replacement	Reduce high rate of damage caused by thermal degradation	HD outer register assembly (hardware centered in air path), Pedaled backplate, material (309 SS) & thickness changes Improved throat seal	Joint: RJM/ B&W/ DWP/ IPSC
Design Review of new Burners	Cost Evaluation Material and thickness study	Design evaluation Finite element analysis	Joint: RJM/ B&W/ DWP/ IPSC
Flame Stabilizers	Improve flame position & stability by improving air flow dynamics	Stabilizers with fixed blading design were added to the inner air zone (between coal flow & outer air zone)	RJM
Secondary Air Flow Balancing	Balance sec air flow thru the burners (inner and outer zones) [+ side to side, top to bottom & front to rear]	Sec air flow tested, shrouding installed on outer registers, backplates set for inner register	RJM/ IPSC
Coal Flow Balancing	Balance primary air and coal flow across the burner row	Clean air flow testing conducted and coal line restrictors added	IPSC
Improved Register Lineup	Change from trying to balance air flow with registers to positioning registers for actual flame conditions	With air balancing conducted (with shrouding and fixing backplates), plus installation of the flame stabilizers, registers could be set for flame conditions	RJM/ IPSC

SECTION 3 - RESULTS OF MODIFICATIONS

One of the primary concerns with making any burner modifications was adverse operational impact on the combustion characteristics. As stated previously, the intent of the burner modifications was to resolve the accelerated mechanical degradation, not to improve upon the combustion. The objective, therefore, was not to allow any of the combustion parameters to get worse and to try, where possible, to improve these conditions.

It should be noted that the same boiler operating parameters were utilized to operate the unit both before and after the burner modifications. These parameters include fuel to air ratio, excess air levels, cooling air flow requirements to out-of-service burners (i.e., same windbox damper positions) and burner front metal temperature alarms. This should give a representative before and after evaluation.

Fly Ash LOI Levels

Carbon content in fly ash is generally determined by a loss on ignition (LOI) test. Impact at IGS on fly ash was a major concern. Following the burner modifications, LOI levels on both units, however, did indeed show an increase. It is felt, however, this increase is within a reasonable range which still allows us to market our fly ash. Prior to any burner modifications, a contract had been arranged to sell fly ash at specific ash quality requirements. The target for the contractor was LOI levels less than 0.55%. So, great emphasis was placed on LOI values and keeping them reasonable.

From a performance perspective (based upon a boiler efficiency loss), one generally won't get concerned with LOI values until they get above 2.0 to 2.5%. Typical LOI values, on a similar boiler design have values ranging from 3.0 to 5.0%, with values as high as 12.0% not uncommon.

Based upon IPSC's experience, it is difficult to try to lower LOIs below 1.0%. With LOIs have to be greater than 1.0%, we feel confident we can identify and assign specific causes to any problems found. For example, problems such as a nonfunctioning windbox damper, bad O_2 probe, a burner register problem, pulverizer problem (such as on a hydraulic loading skid), or a feeder calibration will cause enough of a change in LOIs to increase levels greater than 1.0%. We consistently monitor daily and weekly LOI values and conduct regular boiler walkdowns to identify combustion problems.

Fluctuations of LOI values between 0.30 and 1.00% occur on a regular basis (reference Chart #1 on the daily Unit 1 and 2 average LOI values over the three summer months in 1993). Specific causes of these fluctuations are difficult to pinpoint. Most of the fluctuations are caused by one or a combination of several of the following causes: coal quality fluctuations, fuel to air ratio fluctuations (which includes both coal feeder and oxygen probe calibrations), differences due to out-of-service pulverizer configurations, pulverizer performance condition (degree of wear, loading skid, or rotating throats problems), windbox damper position, as well as a host of other fuel and air discrepancies.

Fly ash LOI values have been extensively sampled by Pozzolanic since January of 1991. For the first two years, as many as 96 fly ash samples are collected and analyzed daily. These daily values have been averaged to compute a monthly composite average. For the purpose of this evaluation, the monthly composite averages are utilized. LOI averages from September of 1991 through September of 1993 for Unit 1 are 0.72%, and for Unit 2 are 0.60%, with the IGS station average at 0.66%. Prior to the burner modifications, Unit 1 averaged 0.65% and Unit 2 averaged 0.57%. After the modifications, Unit 1 averaged 0.75% and Unit 2 averaged 0.60%. This was an increase in LOI levels of 16% on Unit 1 and 6.0% on Unit 2, with a station increase of 11% (reference Table #2 Fly Ash LOI Summary).

Fly Ash Loss on Ignition Summary

	Unit 1	Unit 2	Station
LOI average over entire period (9/91-9/93)	0.72%	0.60%	0.66%
LOI average before modifications	0.65%	0.57%	0.61%
LOI average after modifications	0.75%	0.60%	0.68%
% Change	15.6%	5.8%	11.0%

It should again be noted that the values of LOIs are based upon the monthly averages of the daily values. Day to day averages vary greatly and regularly drop below the 0.55% threshold. Pozzolanic sales of fly ash have steadily increased since July of 1991. June, July, August and September of 1993, have been the highest tonnage collection months to date. (Chart #3 Fly Ash Sales to Pozzolanic.)

Also attached are graphs for the entire period for the monthly LOI averages (Attachment Graph #4 and #5). The individual monthly tally sheets of each day, unit, and east and west valves for the entire period are also included in the attachments (Table #7).

NO_x Emission Levels

NO_x emission levels were another area of major concern. Due to changes in the burner register setup and with the addition of the flame stabilizers, RJM was predicting an improvement in NO_x levels. Both NO_x daily emission averages and 30 day rolling averages did, however, increase slightly on both units. We believe these increases are within acceptable levels, well below state and federal emission limits.

No correlations were attempted to match NO_x increases with other operating factors such as unit load, load variations (dispatch control), coal quality, or other parameters which impact NO_x production over the same period. Many factors determine NO_x levels and include other parameters such as burner register setup, fuel to air ratio, out-of-service cooling air flow, configuration of out-of-service pulverizers, pulverizer condition, boiler bias damper position, cleanliness of the boiler, as well as many others. Since NO_x values are within acceptable values, major research was not conducted to determine and quantify all NO_x contributing factors and their impact.

Daily NO_x emission averages and 30-day rolling NO_x emission average values were placed in a spread sheet over the last 48 months (since 10/1/89). The daily emission averages (DEA) and 30-day rolling averages (30-DRA) computed almost identical results (which gives validity to the original data). The DEA average values will be discussed here, but the 30-DRA averages are also included in the attachments. The 30-DRA values made much more interesting plots. The DEA had too much scatter to give good representative trends.

Prior to any burner modifications, Unit 1's DEA was 0.377 lbs/mbtu (over a 31 month period) and Unit 2's DEA was 0.350 lbs/mbtu (over 25 months). After the modifications, Unit 1's went to 0.385 lbs/mbtu (over 16 months) and Unit 2's went to 0.374 lbs/mbtu (over 21 months). That is a 2.1% increase in NO_x levels on Unit 1 and a 6.8% increase on Unit 2.

The spreadsheet tabulation summary for the DEA and 30-DRA NO_x values is given in Table 8. Daily emission averages and thirty day rolling averages for the entire time frame are given in various combinations and formats for both Units 1 and 2. These are shown in Graphs 9 through 15. The CEM NO_x values are given in Chart 16 for 10/1/89 through 8/31/93.

NO_x Daily Emissions Average (DEA) Summary

	Unit 1	Unit 2	Station
NO_x average (10/1/89-8/31/93)	0.380 lb/mbtu	0.361 lb/mbtu	0.370 lb/mbtu
NO_x average before modifications	0.377 lb/mbtu	0.350 lb/mbtu	0.364 lb/mbtu
NO_x average after modifications	0.385 lb/mbtu	0.374 lb/mbtu	0.379 lb/mbtu
% Change	2.1%	6.8%	4.4%

<u>LOI to NO_x Relationship</u>

The relationship between LOI's in fly ash and NO_x emissions are inversely proportionate. A decrease in excess air levels will generally decrease NO_x emission levels, but will adversely increase LOI levels in fly ash. An optimum balance is sought to have the lowest LOI levels possible (to meet fly ash sales obligations) and lowest NO_x levels (state and federal emission requirements and IPSC environmental consciousness). After considerable evaluation, the optimum excess air levels have been determined as the original excess air targets recommended by B&W of 3.20% O_2 at full load (one pulv o/s).

Eyebrow Formation/ Ash Fusion Temperatures

Eyebrow formations above and to the sides of the burners have been an on-going problem since start-up. Evaluating the severity of eyebrow formulations is highly subjective. The hope was that with the air and fuel flow balancing efforts, eyebrow severity would be reduced. It would be difficult to say, matter-of-factly, that eyebrow formation has been greatly reduced. Eyebrows still keep recurring. With the extended outage cycle of twelve month duration, it doesn't seem to pose major problems with burner or scanner operation.

Eyebrow problems won't totally be eliminated unless coal purchased excludes coal which doesn't meet ash fusion temperature specifications for the furnace design. Approximately half of all supplies cannot meet this requirement.

Burner Front Temperatures

It has been difficult to distinguish temperature reductions on individual burners. Only within recent outages have burner thermocouples on Unit 2 been brought to a reliable status. Unit 1 thermocouples were not replaced with care (reused previous thermocouples) as to installation quality or location on the new burners. As a result, available data is not considered trendable. Based upon temperature indications, however, it is clear burner temperatures have not risen for the same windbox damper locations (i.e., same cooling air flow).

SECTION 6 - CONCLUSIONS

Based on both windbox and fireside inspections since modifications, the new burners and associated hardware are documented to be in excellent condition. All current information supports the conclusion that the Unit 1 burners should operate reliably throughout the design life of the plant. Degradation on the Unit 2 burners appears to have subsided sufficiently to indefinitely postpone burner replacement on that unit.

The approach taken to resolve the burner overheating problem was to employ all the recommendations at hand. These, at the time, included flame stabilizer installation on Unit 2, new burner design assemblies with flame stabilizers installed on Unit 1, new burner lineup on the inner and outer air registers and backplate settings, secondary air flow balancing of inner and outer zones, and also primary air and coal flow balancing.

Which alteration made the largest contribution to addressing the overheating problem is tough to debate, although all are believed to have significantly contributed to the overall success. Due to the urgency to resolve the matter at hand and to avoid a lenghty testing phase, all recommendations were applied at the same time.

Investigations continue into the nozzle flaring phenomenon observed at a small number of burner nozzle tips. This problem is being monitored carefully in an attempt to correlate suspected recirculation patterns and nozzle degradation on specific burners. Likewise, cost effective resolutions to concerns regarding intermittent burner line fires are being pursued. An early warning detection system installed during the 92-93 fiscal year has been successful in eliminating major equipment damage which previously resulted from burner line fires.

The inner air zone turning vanes or "stabilizers", located near the burner throat, have been successful in helping stabilize flame characteristics throughout the load range. Earlier concerns regarding the long-term survivability of the stabilizers (due to overheating and/or pluggage ash) have proven to be unfounded. However, several stabilizers have been replaced due to flaring of the coal nozzle. These nozzles typically droop and force the stabilizer out of round, causing buckling of some of the vanes in the stabilizer.

Efforts to balance combustion air by installing shrouds and stabilizers at each burner have proven valuable. Proper cooling and combustion requires both proper volume flow and swirl in each burner zone. By allowing proper register door settings for required "swirl" control, the shrouds and stabilizers have markedly improved consistency of flame shape, color and ignition zone location at all loads. At the same time, elimination of inner burner degradation on Unit 1 and the significantly reduced rate of degradation on Unit 2, substantiates the improvements in airflow distribution.

Burner combustion performance tracking shows LOI and NO_x at slightly higher levels as were seen prior to the burner modifications. Eyebrow formation and burner front temperatures have been at the same levels as before any modifications. Operationally, there have not been any significant changes in the combustion parameters.

It could be aptly argued that the stress analysis performed by RJM saved the $1,600,000 cost of another set of burners that would have been necessary when the B&W redesigned burner ultimately failed again due to thermal stress. However, based solely on the avoided cost of the B&W recommended Inconel 800H material, the RJM thermal analysis alone saved $620,000. The cost of all RJM services including the 96-310 stainless steel stabilizers and air flow balancing was approximately $350,000.

SECTION 7 - RECOMMENDATIONS

IPSC recommends that the flame stabilizers, installed on both units be left in place and fully maintained. Also recommended, based upon inspections to date, is that the Unit 2 burners not be replaced until warranted by observing additional structural degradation. This degradation, however, is likely due to thermal stresses inherent in the original B&W design burner.

We recommend and will continue to ensure that, the burners be carefully inspected at each opportunity. Of particular interest is the long-term condition of the registers, stabilizers and nozzles.

More investigative testing will be conducted on the burner flame front position to address causes of the coal nozzle flaring. Testing is planned, prior to the Unit 2 Fall 1993 outage, to determine the distance from the end of the coal nozzle to the beginning of the flame front. By determining where the flame fronts are located, correlations can then be applied and action taken to avoid nozzles from flaring due to flame overheat.

Additional testing is also planned on the coal burner transport lines. A nondirectional velocity probe will be used to test dirty air (primary air and coal flow) velocities. Several different techniques have been used in the past, including clean air flow, dirty air flow and roto-probe, with conflicting results.

If the direct velocity measurement proves successful as hoped, an additional interaction of coal line restrictor changeouts will be recommended.

Additional analysis will also be conducted on the causes of burner line fires. Since the installation of temperature switches on the coal elbows, the occurrences of fires have greatly diminished due to their early detection and intervention. However, fire initiation is still present within the coal line. We recommend proceeding with conducting an aerodynamic analysis of the coal piping to determine potential causes of this problem.

One of the results of the secondary air flow balancing program was the identification of vortexing around the burner (high severity of nonuniform air distribution around the burner). It was recommended by RJM that this warranted additional windbox modeling to resolve this issue.

It is felt that due to the structural logistics of the windbox design, little can be done physically to resolve this issue.

Addition of windbox air flow measuring devices is not being recommended. It is felt that due to the secondary air flow balancing conducted, that this is no longer required. Air flow balancing has resolved in-service to out-of-service (low flow to high flow) problems.

LIST OF ATTACHMENTS

Attachment #1 - 1987 Spring Outage Inspection Report, Unit 1

Attachment #2 - 1987 Fall Outage Inspection Report, Unit 1

Attachment #3 - 1988 Spring Outage Inspection Report, Unit 1

Attachment #4 - 1989 Spring Outage Inspection Report, Unit 1

Attachment #5 - Energy and Environmental Research Corp Burner Report

Attachment #6 - William Newkirk Burner Report

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